2.—Diet of Kangaroos (Megaleia rufa and Macropus robustus) and merino sheep near Port Hedland, Western Australia

by G. M. Storr*

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Abstract

The diet of kangaroos and sheep grazing freely in the same area on Mundabullangana Station was ascertained in four seasons in 1961. Seasonal variation was studied in the nitrogen and water content of food plants and thus also of the three diets. Estimates were obtained in 1962 of the daily consumption of dry matter by kangaroos. Observations were made on the habitat preferences of the two kangaroos and on their seasonal movements and weight changes.

Introduction

The Pilbara region of the northwest of Western Australia was formerly a large producer of wool. Since the mid-1930s sheep numbers have declined and several stations have been abandoned. Ealey and Suijdendorp (1959) attribute this decline to misguided stocking policies and the consequent deterioration of pastures. The pastoralists, however, generally blame the kangaroos, whose numbers are said to have increased enormously since the leases were first taken up.

Little was known of the diet of the kangaroos and sheep, and the writer was directed to make a survey, using the methods developed for Rottnest Island quokkas (Storr 1964). Midna Paddock on Mundabullangana Station (between Port Hedland and Roebourne) was chosen for study. Both the marloo *(Megaleia rufa)* and euro *(Macropus robustus)* were plentiful in the area, and the writer was assured that the paddock would be stocked with sheep throughout the period of study (1961-62).

Environment

Physiography and climate

The study area (see map, Fig.1) is situated 6-10 miles from the sea at an elevation of 20-80 feet. The land rises imperceptibly as one goes inland, and the prevailing flatness of the country is broken only by minor dissection in the vicinity of the Little Yule River and by slightly higher areas that can seldom be called dunes. The soils are mostliy sandy to clayey loams, usually of no great depth over impervious clay, which is frequently exposed in wind-eroded areas to form claypans. The Little Yule is a distributary of the Yule River and only flows when the latter is in flood; otherwise it contains no water apart from a few small pools. The claypans retain water for some weeks after heavy rain. During the remainder of the year the kangaroos are as dependent as the sheep on the water in mill troughs.

The climate is characterised by aridity and great summer heat. The mean annual rainfall is 13.6 inches, most of it coming in late summer when cyclonic storms sweep inland from the north. Convectional rain is less frequent here than in the hilly interior of the Pilbara region; hence the relative dryness of December and January. A little rain may reach the area from the south in winter. The period October to December is usually one of unrelieved drought and heat. In Table 1 climatic data (C'wealth Bureau of Meterology, 1956) are given for Roebourne (80 miles to the WSW) rather than for Port Hedland (40 miles to the ENE)—Roebourne's similar distance from the sea makes it more representative of the study area, for relative humidity decreases and temperature increases rapidly as one leaves the coast. Included in the table are monthly rainfall at Mundabullangana for 1960-62 and the monthly means for 34 years (these data were kindly supplied by Mr G. W. Mackey, Deputy Meteorologist, Perth).

* Department of Zoology, University of Western Australia. Present Address: Western Australian Museum, Perth.

TABLE 1

Mean daily maximum and minimum temperature (°F) and relative humidity (%) at Roebourne, and monthly rainfall (inches) at Mundabullangana

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Max. temp.	101	101	98	94	86	79	79	83	90	94	101	102
Min. temp.	79	79	77	71	64	58	55	57	61	67	73	77
Rel. humidity	52	53	55	46	48	51	47	48	41	43	42	47
Rainfall, mean	2.2	3.3	3.7	1.3	1.0	0.9	0.4	0.3	0.0	0.1	0.1	0.4
Rainfall, 1960	2.6	8.0	....	....	0.9	0.1	....	....	....	....	....	....
Rainfall, 1961	9.1	8.5	4.2	....	....	....	....	....	....	....	....	....
Rainfall, 1962	4.0	1.9	0.0	0.1	0.3	0.5	0.1	....	....	....	....	....

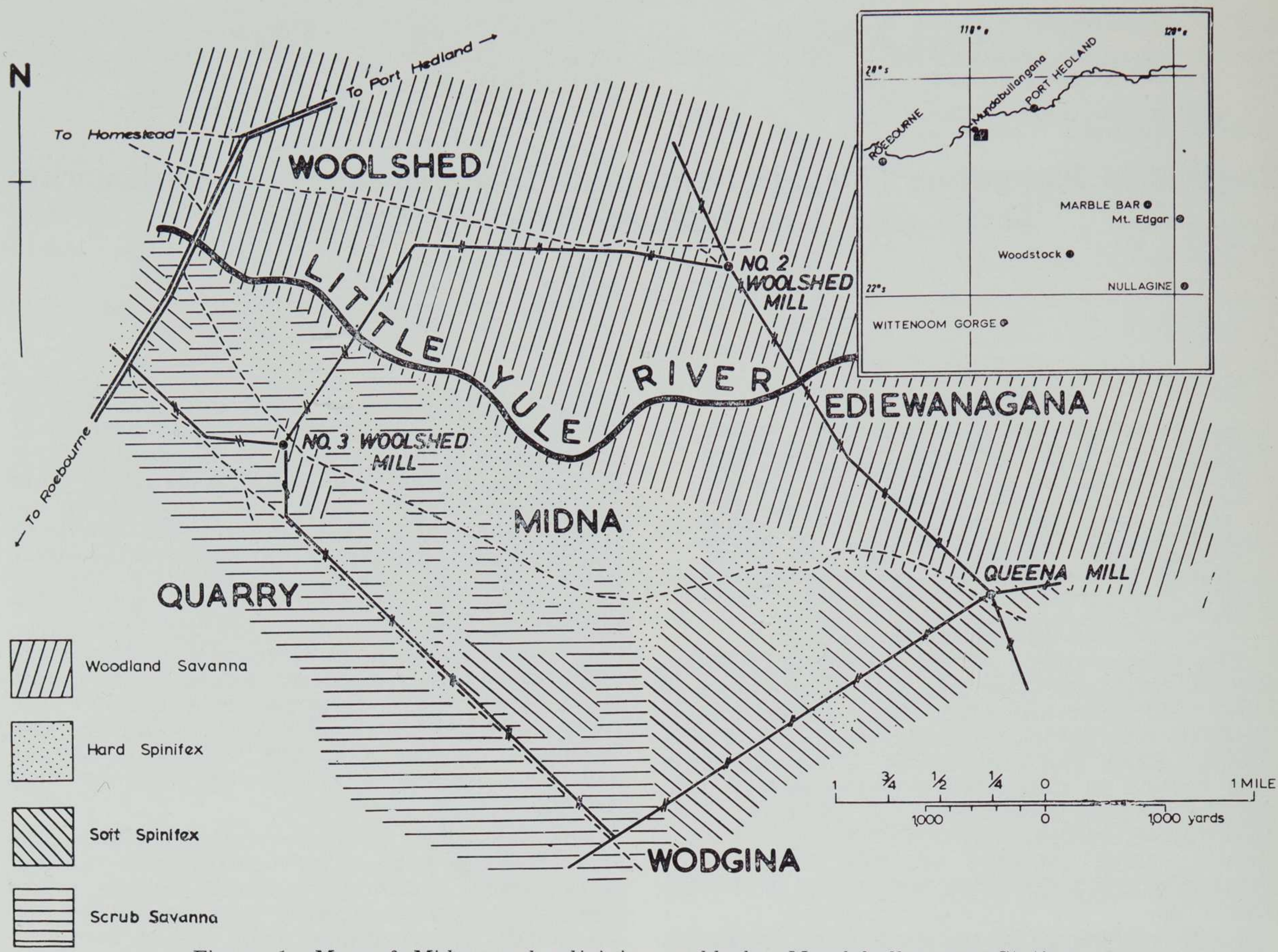

Figure 1.—Map of Midna and adjoining paddocks, Mundabullangana Station.

Vegetation

The vegetation of the area is divisible, from the viewpoint of kangaroo habitats, into four broad types: (1) Woodland Savanna, (2) Hard Spinifex, (3) Soft Spinifex, and (4) Scrub Savanna.

Woodland savanna occupies most of the country between the Yule and Little Yule Rivers, which themselves are lined with forests of river gum *(Eucalyptus camaldulensis)* and cajuput *(Melaleuca leucadendron)*. Back from the rivers, the composition of the savanna depends on soil texture and frequency of inundation. Heavy, low-lying soils carry river gums and soft grasses (i.e. grasses other than *Triodia*), especially *Cenchrus, Eragrostis,* and *Eriachne* spp. As the land rises, cabbage gum *(Eucalyptus aspera)* and whitewood *(Atalaya hemiglauca)* become successively dominant, the principal grasses being buffel *(Cenchrus ciliaris)*, birdwood *(C. setigerus)* and weeping grass *(Chrysopogon latifolius)*. Finally on the lightest soils there only remain low trees of parkumara *(Owenia reticulata)*, *Acacia sclerosperma,* kanji *(A. pyrifolia)* and corkwood *(Hakea lorea)*. By this time the *Cenchrus* spp. have been largely replaced by soft spinifex *(Triodia pungens)* and spear grasses *(Aristida* spp.). Woodland savanna is the stronghold of the marloo, though the euro becomes increasingly common in the drier and scrubbier parts of the savanna.

Hard spinifex occupies a considerable part of the study area south of the Little Yule. The soil is generally clayey, and the vegetation is dominated by *Triodia longiceps,* whose stiff pungent foliage is disdained by kangaroos and sheep. Its inflorescence, however, is surprisingly rich in nitrogen and provides good foodder in late summer. On the heaviest soils *T. longiceps* is replaced by another hard spinifex, *T. secunda.* Trees are absent and the only shrub present is the low, succulent *Trianthema turgidifolia.*

As the country becomes higher and the topsoil sandier, hard spinifex gives way to soft spinifex *(T. pungens)*. Shrubs and low trees (especially kanji) begin to appear, but neither are as conspicuous as the great red termitaria of *Nasutitermes triodiae.* The dominant kangaroo here is the euro, which finds daytime shelter among isolated thickets of *Carissa lanceolata,* beneath the larger kanji, and occasionally in the shade of termitaria.

With increasing elevation and depth of sand, shrubs become numerous and varied, e.g. *Acacia translucens, A. holosericea, Pluchea tetranthera,* and *Cassia* spp. The dominant (and often the only) grass is *Triodia pungens.* There is a good variety of perennial herbs and low shrubs (mainly leguminous and malvaceous), which however are only common where the spinifex has been checked. Since these herbs and low shrubs are much more palatable to sheep than the old tussocks of spinifex, their growth is induced by burning the spinifex, which itself is sought by sheep when young. The marloo is a sporadic visitor from neighbouring habitats and is found only on burnt areas. Euros are plentiful everywhere and have no difficulty in finding suitable daytime shelter in this zone of abundant shrubs and low trees.

In the foregoing account only perennial elements of the vegetation have been noticed. During and after good summer rains (as in 1961) there is much annual herbage, especially grasses, the commonest of which are *Dactyloctenium radulans, Eragrostis brownii, E. xerophila, Eriachne aristidea, E. obtusa, Xerochloa laniflora, Ichnanthus australiensis, Paspalidium clementii,* and *Perotis rara.* Moreover, such perennial grasses as *Chrysopogon latifolius* and *Cenchrus* spp., which may be reduced to little more than their rootstocks by the end of the dry season, rapidly resume their growth until much of the riverain country looks like a wheatfield. Dicotyledons are only conspicuous where the ground has been relatively bare, as around mills or in burnt country. The commonest species are *Commelina ensifolia, Trichinium obovatum, Gomphrena canescens, G. affinis, Ptilotus murrayi, Boerhaavia diffusa, Mollugo molluginis, Calandrinia creethae, Portulaca oleracea, Cleome viscosa, Tephrosia bidwillii, Euphorbia australis, E. atoto,* and *Seddera media.*

Movements and habitat preferences of the kangaroos

The study area was visited in February, May, August and November 1961. On each trip kangaroos (euros and marloos of both sexes and all ages after weaning) were sought in the evening with a spot-light and shot from a vehicle with a 0.26 inch rifle fitted with telescopic sights. Three standard routes were traversed at least twice each trip: (1) the northern track (from the highway eastwards to No. 2 Woolshed Mill, thence southeastwards along the Midna-Edie-wanagana boundary for half a mile); (2) the middle track (from the highway southeastwards to Queena Mill via No. 3 Woolshed Mill; and (3) the southern track (along the southwestern boundary of Midna to the extreme southern corner of the paddock). The northern track was traversed on additional occasions to build up marloo samples.

When an animal was shot, it was dragged to the vehicle, sexed, and weighed. Next day its location when last feeding (marked temporarily the previous evening) was fixed, usually by compass triangulation to one or more mills. A one-chain transect was made at the location so as to obtain the percentage cover of perennial vegetation. In addition, all plant species, annual and perennial, within a 2-chain radius of each location were noted and the degree to which they had been grazed.

Results.

Table 2 gives the distance of kangaroo locations from nearest mill, and Tables 3 and 4 the density and composition of the plant cover.

TABLE 2

Mean distance (yards) of kangaroo locations from nearest mill. The figures in brackets are the percentage of locations within half a mile of a mill

	Euro	Marloo
February	1440 (39)	1780 (26)
May	1070 (54)	840 (50)
August	1230 (44)	570 (81)
November	990 (43)	590 (86)

TABLE 3

Mean percentage (by area) of perennial cover and bare soil at euro locations. Marloo data in brackets.*

	Perennial Cover	Bare Clay and Clayey Loam	Bare Sand and Sandy Loam
February	26 (22)	17 (40)	57 (38)
May	20 (15)	16 (35)	64 (50)
August	18 (17)	10 (27)	72 (56)
November	21 (8)	19 (41)	60 (51)

* Bare soil includes ground carrying ephemeral vegetation.

Remarks

Since the mean distance from the nearest mill of all points on the traverses was 1490

TABLE 4

Mean percentage composition (by area) of perennial ground cover at euro locations. Marloo data in brackets.

	January	May	August	November
Grasses				
Cenchrus spp.	14·3 (53·6)	32·8 (48·9)	24·9 (51·6)	45·2 (22·1)
Chrysopogon latifolius	2·7 (—)	4·5 (4·2)	0·7 (—)	1·4 (3·3)
Eragrostis spp. .... } *Eriachne* spp. .... }	— (2·2)	— (3·3)	— (20·3)	0·3 (12·5)
Triodia longiceps	15·0 (5·4)	1·3 (9·7)	13·7 (1·1)	2·1 (5·0)
Triodia pungens	53·6 (30·1)	48·8 (29·0)	54·8 (24·0)	42·3 (39·2)
Triodia secunda	1·2 (3·9)	0·4 (—)	— (—)	— (3·3)
Total grasses	86·8 (95·2)	87·8 (95·1)	94·1 (97·0)	91·3 (85·4)
Herbs and Shrubs				
Acacia spp.	1·4 (—)	3·1 (—)	0·4 (0·4)	0·9 (—)
Aerva javanica	— (0·2)	— (—)	— (—)	— (1·1)
Bonamia rosea	— (—)	0·3 (—)	— (0·4)	0·2 (5·6)
Cassia spp.	1·5 (—)	1·8 (1·1)	1·7 (0·4)	0·7 (5·6)
Corchorus walcotti	3·1 (—)	3·7 (1·2)	2·4 (—)	5·4 (0·6)
Ipomoea muelleri	0·3 (—)	0·9 (2·4)	— (0·7)	0·3 (—)
Pluchea tetranthera	3·0 (—)	1·9 (—)	0·8 (1·1)	0·5 (—)
Trianthema turgidifolia	1·4 (3·7)	— (—)	— (—)	— (—)
Other species	2·5 (0·9)	0·5 (0·2)	0·6 (—)	0·7 (1·7)
Total dicots	13·2 (4·8)	12·2 (4·9)	5·9 (3·0)	8·7 (14·6)

yards, it is clear from Table 2 that the kangaroos were distributed in February (in contrast to other seasons) independently of the mills. At first sight this independence may seem to have been due alone to the wide dispersal of water—the Little Yule was flowing and all claypans were filled, so that the mean distance from nearest water of marloo and euro locations was 200 and 340 yards respectively; whereas in subsequent trips the nearest water to almost all animals was in fact at the mills. However, the situation was not as simple as that, and the implication that marloos were more dependent than euros on mill water was not supported by other observations.

In February a considerable proportion of the marloos were obtained on the middle track at large claypans between No. 3 Woolshed and Queena Mills (hence the high mean distance of locations from nearest mill). They were feeding on the lush growth of annual grasses round the edge of the water. By May the water had disappeared and also all the herbage, and no marloos were obtained there during that or later trips. There was simply little suitable food for them in an area where the vegetation in the dry season consisted mostly of hard spinifex.

As the data in Tables 3 and 4 indicate, the marloo prefers sparsely vegetated country and especially the heavier soils which support soft grasses rather than *Triodia pungens* and scrub. It shuns the latter, except where after a burn there is a regeneration of young grasses and herbs. It so happens that conditions favourable to marloos are more ofter encountred near mills than distant from them. The concentration of watering sheep round mills inhibits the growth of scrub; and the bare, heavily manured soil favours *Cenchrus* over *Triodia*. Controlled burns, out of consideration for the sheep, are carried out in scrub and *Triodia pungens* within easy walking of mills. Thus the apparent drift of marloos towards mills in the dry season could be attributed to the shrinking of the food supply as well as to that of water.

The average distance of euro locations from mills was inflated in February by the large numbers taken towards the southern corner of Midna paddock, where the vegetation consisted mostly of old unburnt *Triodia pungens*. In February the *Triodia pungens* was flowering and provided the euros with abundant fodder. Later in the year when the inflorescences had gone and the foliage had become resinous, the euros increasingly turned to other sources of food. Again, it is hard to separate the effect of availability of water from that of food when interpreting the general dry-season withdrawal of animals to the vicinity of mills. Whatever their causes, these movements brought the two kangaroos (and sheep) into closer contact towards the end of the year.

Composition of the diet

A sample of faeces was taken from the rectum of each kangaroo that was shot. The vicinity of all kangaroo locations was searched for fresh sheep faeces; if present, one or two samples were collected, each apparently from a single animal. These were augmented with material from grazing flocks, whether or not they were at a kangaroo location. On returning to Perth, faecal samples were dried, ground, prepared into slides and examined microscopically as in Storr (1961).

Since grass was the major component in the diet of all three animals, it was desirable to identify grass epidermis to species. Generally it was not difficult to identify grasses to genus; but because intra-specific variation in epidermal characters often overlapped that between congeneric species, identification depended unduly on the knowledge of what was present at each location. Moreover, the animals were obviously eating some species (usually identifiable to genus) that were not collected by the writer. Most of the data have therefore been lumped under genera.

The identification of dicotyledons posed even greater problems, not because of intrinsic difficulties, but because their great variety (out of all proportion to their dietary importance) precluded the preparation and study of all but a fraction of the items eaten. This deficiency mainly affects the sheep data, which for other reasons are not so reliable as those for the kangaroos. Apart from the different way of sampling the sheep, particles in their faeces were so small as to render their identification and quantification difficult and uncertain.

Results

See Table 5.

TABLE 5

Mean percentage composition (by area of epidermis in faeces) of the diet of kangaroos and sheep

	February			May			August			November		
	Euro	Marloo	Sheep	Euro	Marloo	Sheep	Euro	Marloo	Sheep	Euro	Marloo	Sheep
Aristida spp.	1	....	0	11	2	8	22	13	5	33	29	1
Cenchrus spp.	7	30	42	20	25	21	32	54	37	34	34	37
Chrysopogon latifolius	11	14	3	7	6	13	4	3	1	4	4	6
Dactyloctenium radulans	1	26	5	....	....	....	....	....	....	....	....	....
Eragrostis spp.	3	6	9	2	9	1	0	6	1	0	3	1
Eriachne spp.	....	1	3	10	12	4	4	2	4	1	1	3
Ichnanthus australiensis	0	0	9	1	2	1	....	....	....	....	....	....
Paspalidium clementii	2	3	12	1	....	....	....	....	....	....	1	0
Perotis rara	1	4	2	....	....	....	....	....	....	....	....	....
Triodia spp.	70	12	7	30	17	11	31	11	17	19	12	15
Other grasses	1	2	1	1	1	0	0	1	....	....	....	0
Non-grasses	2	3	7	18	26	41	7	10	35	9	15	37

Remarks

In February, food and water were so abundant and widely dispersed that the kangaroos and sheep could exercise their food preferences without restraint. As a result, they tended to segregate, even though all three species were feeding largely on grasses. The euros were mostly eating *Triodia* (especially their inflorescence); the marloos, *Cenchrus, Dactyloctenium* and *Chrysopogon*; and the sheep *Cenchrus Paspalidium* and *Eragrostris*. The fact that *Cenchrus* was the major food item of both marloos and sheep was unimportant, for there was far more of it than either of them could eat.

Most of the annual grasses that came up with the January rains (e.g. *Dactyloctenium, Paspalidium, Perotis* and *Eriachne japonica*) had disappeared by May, when a new but smaller crop was maturing (e.g. *Aristida* spp. and *Eriachne aristidea*. Meanwhile the spinifex inflorescences had withered away and the leaves of *Triodia pungens* in the absence of rain had become coated with resin. The euros were eating much less *Triodia* than earlier and much more *Cenchrus* and such dicots as *Bonamia rosea* and *Hybanthus enneaspermus*, as well as sharing with the sheep and marloos the new crop of annual grasses. The change in diet of the marloos was smaller; it was partly brought about by the increased number of animals on spinifex burns, which resulted in greater consumption of dicotyledonous herbage (especially *Bonamia*) and young *Triodia pungens*. The sheep undertook a similar but more marked shift to burnt country, where they ate a much wider variety of dicots than either of the kangaroos.

Despite the dwindling supply, consumption of *Cenchrus* by all species increased in August. Both kangaroos, but not sheep, were eating more spear grass (*Aristida*) and less dicotyledonous herbage, which was then becoming scarce on the spinifex burns.

By November the euros were hardly eating more spinifex than were the marloos and sheep. Indeed all three species were perforce eating much the same things. The only considerable differences were the small intake of spear grass by sheep and their large intake of dicots. Few of the latter were specifically identified in faeces, but observations indicated that in early summer the sheep were increasingly browsing *Atalaya hemiglauca* and kapok (*Aerva*). Though neither of these was eaten much, if at all, by kangaroos, there can be little doubt that they were seriously depriving the sheep of other sources of food in the last few months of the year. While most plants of *Cenchrus* had grown rank and finally withered away, a few of them had been grazed low all the year; and where the water supply was better than usual, as between wheel tracks and at mill overflows, there was a more or less continuous growth of fresh foliage. However, the demand towards the end of the year for these last remaining sources of green grass was excessive, and they were rapidly depleted.

Nitrogen and water content of food

On each trip at least 20 g (dry weight) of terminal foliage was collected from five or more individual plants of all species known to be eaten in substantial amounts. The samples were weighed in the field to the nearest 0.5 g, and again in Perth after oven-drying to constant weight. The material was then ground and analysed for nitrogen by the Kjeldahl method, as modified by Willits, Coe and Ogg (1949).

Nitrogen and water content were applied to the dietary data (summarised in Table 5) to give the mean nitrogen and water content of each species' total ingesta.

Results

See Tables 6 and 7.

TABLE 6

Nitrogen content (% dry weight) of major food items
Water content (% wet weight) in brackets

	February	May	August	November
Grasses				
Aristida spp.	....	0·7 (41)	0·7 (39)	....
Cenchrus spp.	1·4 (82)	1·4 (61)	1·3 (64)	0·8 (31)
Chrysopogon latifolius	1·6 (80)	0·8 (61)	0·8 (48)	0·9 (42)
Dactyloctenium radulans	1·5 (81)	....	....	....
Eragrostis spp.	1·7 (65)	0·6 (38)	0·5 (14)	0·7 (14)
Eriachne spp.	1·7 (72)	0·9 (37)	....	....
Paspalidium clementii	2·5 (87)	....	....	....
Triodia longiceps	1·4 (55)	1·0 (28)	1·2 (39)	0·8 (17)
Triodia longiceps (I)	1·9 (59)	....	....	....
Triodia pungens	0·8 (51)	0·8 (51)	0·5 (22)	0·7 (14)
Triodia pungens (I)	1·1 (44)	....	....	....
Triodia pungens (S)	....	0·9 (52)	....	0·6 (37)
Triodia secunda	1·6 (71)	1·5 (48)	1·7 (44)	1·3 (29)
Triodia secunda (I)	1·4 (56)	....	....	....
Non-grasses				
Aerva javanica	1·7 (74)	1·6 (40)	1·3 (56)	1·8 (67)
Atalaya hemiglauca	....	....	....	1·6 (63)
Bonamia rosea	....	1·8 (53)	....	....
Hybanthus enneaspermus	....	1·5 (63)	....	....
*Leguminosae**	....	2·8 (69)	2·0 (58)	1·1 (34)

I, inflorescence ; S, seedings.

* Average of *Crotalaria crispata*, *C. trifoliastrum*, *Indigofera monophylla*, *Psoralea martini*, and *Tephrosia bidwillii*.

TABLE 7

Nitrogen content (% dry weight) of ingesta. Water content (% wet weight) in brackets.

	Euro	Marloo	Sheep
February	1.3 (62)	1.6 (77)	1.7 (79)
May	1.1 (55)	1.2 (57)	1.2 (60)
August	1.0 (48)	1.1 (53)	1.2 (54)
November	0.8 (31)	0.8 (30)	1.0 (37)
Year	1.0 (49)	1.2 (54)	1.3 (58)

Remarks

From maxima in February, the nitrogen and water content of herbage generally decreased throughout the year. The decline in nutrients was most pronounced in soft grasses, somewhat less in *Triodia*, and least in dicots.

The sheep, feeding almost exclusively on soft grasses in the wet season and to a large extent on dicots in the dry season, maintained throughout the year a level of nitrogen and water intake (from herbage) that was about 20% greater than in euros. In both respects the marloos were usually intermediate—somewhat nearer to the sheep in the first half of the year, and nearer to the euros in the second. Of the three species the marloos thus experienced the sharpest decline in nutrient levels, e.g. a 48% drop in nitrogen between February and November.

Daily intake of dry matter by kangaroos

The principle behind the method described below is that in Storr (1963), viz. that daily intake is on average equal to daily loss of dry matter from the stomach. But owing to the difficulty of catching and holding kangaroos alive, it was necessary to modify the procedure used with *Setonix*.

Adult kangaroos of a given species and sex were shot in the early morning after they had ceased to feed, and again in the afternoon before they resumed feeding (the mouths of shot animals were searched for feed, so as not to include in samples any animals that were feeding). Entire stomachs were dissected out and preserved in 44-gallon drums of 70% alcohol. In Perth the stomachs (and their contents) were oven-dried to constant weight.

Assuming (1) a linear rate of loss of dry matter from the stomach, and (2) no difference between samples in mean weight of stomach (exclusive of contents), the difference in mean dry weight of stomach plus contents between morning and afternoon samples was extrapolated to give the mean daily rate of loss from the stomach and the presumed intake of dry matter.

Male euros were sampled between 27 February and 2 March 1962, and female marloos between 26 October and 2 November 1962.

Results

See Table 8 and 9.

TABLE 8

Adult male euros: mean dry weight of stomach plus contents in morning and afternoon (standard deviations in brackets)

	a.m.	p.m.
Number in sample	6	7
Mean body weight (kg)	33.5 (2.2)	33.9 (2.6)
Mean time shot (hr and min)	08.20 (28)	05.41 (20)
Weight of stomach + contents (g)*	776 (84)	606 (67)

* Mean rate of loss: 170 g in 9.35 hours, i.e. 436 g/day.

TABLE 9

Adult female marloos: mean dry weight of stomach plus contents in morning and afternoon (standard deviations in brackets)

	a.m.	p.m.
Number in sample	9	10
Mean body weight (kg)	23.5 (3.4)	22.4 (2.0)
Mean time shot (hr and min)	06.49 (42)	5.08 (36)
Weight of stomach + contents (g)*	617 (72)	497 (89)

* Mean rate of loss: 120 g in 10.33 hours, i.e. 279 g/day.

Remarks

For the comparison of metabolic phenomena, including DMI (daily dry matter intake), between animals of different size, Brody (1945) recommended adjusting for body weight not directly but by the power of 0.73. Thus DMI in the adult male euros was 33.6 g/kg $W^{0 \cdot 73}$, a value that agrees well with that observed in captive euros. Six females (mean weight 12.7 kg) had a mean DMI of 231 g (Brown, 1964), which is equivalent to 34.5 g/kg $W^{0 \cdot 73}$. A male euro (weight 17 kg), kept by Ealey (pers. comm.) at Woodstock (120 miles southeast of Mundabullangana) and fed on buffel grass (averaging 44% water and 0.7% nitrogen), had a mean DMI of 259 g, i.e. 32.7 g/kg $W^{0 \cdot 73}$.

DMI in the adult female marloos at Mundabullangana was only 28.4 g/kg $W^{0 \cdot 73}$. Ealey also observed a low DMI in a young marloo (10 kg) at Woodstock. Fed the same diet as the euro cited earlier, its DMI averaged 126 g, i.e. 23.5 g/kg $W^{0 \cdot 73}$. Nevertheless it is doubtful whether marloos generally have a lower intake than euros. First, Brown (1964) obtained much the same values in the two species. Second, the Woodstock marloo was upset by the experiment (Ealey pers. comm.). Third, the low intake observed by me was probably due to drought conditions. Of all adult female kangaroos examined in October-November 1962 (euros as well as marloos) only one had a furred joey in the pouch. All other joeys were small and naked, and juveniles at heel were fairly large. Evidently the diet then and for some time previously was inadequate for producing milk beyond the requirements of small joeys. Sadleir (1961) observed no such failure to rear joeys to weaning in the two years of his fertility studies at Mundabullangana, but then neither of those years (1960 and 1961) was so dry as 1962. Moreover, spring 1962 was abnormally hot.

While it is unlikely that DMI is generally lower in marloos than euros, it is probably much lower in kangaroos than sheep. Fels, Moir and Rossiter (1959) investigated the organic matter intake (i.e. dry matter less ash) in six merino wethers at Kojonup in the southwest of Western Australia. On a grass-dominated pasture, daily intake remained fairly steady from September to December, the mean rate being 55 g/kg $W^{0 \cdot 73}$. On a clover-dominated pasture mean daily intake declined from 78 g in September to 51 g in October and 40 g in December. The intake of sheep under the very different conditions in the Pilbara could well be lower, but hardly so low as to justify the popular belief that a kangaroo eats twice as much as a sheep.

Seasonal changes in body weight of kangaroos

Kangaroos continue to grow after attaining sexual maturity. As small samples such as these may vary considerably in age structure, mean weight alone does not accurately reflect seasonal changes in weight. For example, the large increment in August 1961 of young adult female marloos completely masked the general weight gain over the previous three months. Some allowance must therefore be made for inter-sample differences in real size of animals. Unfortunately pes length, the only linear measurement taken, is poorly correlated with real size. Male euros, for instance, have been examined with almost the same pes length but differing by 14 kg in weight. Growth in adult females is much slower than in males, so that inter-sample differences in real size are small and observed weights require little adjustment.

The overall mean pes length of adult female marloos and euros was 291 and 247 mm respectively. Observed weight has been adjusted to these lengths, using the relation established by Sadeir (1961) between pes length and body weight in large samples of Mundabullangana kangaroos. For ease of comparison, mean adjusted weight of each sample has also been expressed as a percentage of the weight in August.

Results

See Table 10.

TABLE 10

Weight of adult female euros in 1961, with marloo data in brackets

	February	May	August	November
Number in sample	17 (13)	19 (14)	12 (9)	16 (13)
Mean pes length (mm)	249 (296)	247 (292)	247 (283)	246 (287)
Mean obs. weight (kg)	14·4 (20·5)	14·9 (22·7)	16·4 (22·5)	15·7 (22·4)
Mean adj. weight (kg)	14·2 (19·6)	14·9 (22·6)	16·3 (23·5)	15·8 (22·9)
Index	87 (83)	92 (96)	100 (100)	97 (97)

Remarks

The weight of the kangaroos in 1961 was probably lowest in early January, at the onset of the summer rains. Even after three or four weeks good feeding, weights were still very low in February and much lower than in other trips. Dry season weight losses could thus amount to 20%.

Though the samples are not really adequate for interspecific comparisons, the marloos apparently put on weight quicker than the euros. This could well have been so; for the soft grasses, which constituted the greater part of their late summer diet, were not only superior in nitrogen to the euros' fare, but undoubtedly also in energy and digestibility.

Between August and November both species lost only 3% of their weight, despite the complete lack of rain since the preceding March and the continuous decline in nutrients. Euros began to lose weight only when the nitrogen content of their food fell below 1%, or in other words, when the daily intake of nitrogen was less than 330 mg/kg $W^{0.73}$. This value is close to G. D. Brown's estimate of the euro's minimal requirements of dietary nitrogen under experimental conditions, viz. 309 mg/day/kg $W^{0.73}$ (Brown, 1964).

Discussion

The various aspects of this research have been discussed in the body of the paper. It now remains to assess their significance in the total Pilbara scene. Before doing so, it will be helpful to recapitulate the present results and to indicate how their generality may be limited by peculiarities of time and place.

Recapitulation

The rains of January-March 1961 were very much above average. Surface water was abundant and widespread, as were annual grasses, ephemeral herbs and rejuvenating perennials. Euros, marloos and sheep were largely segregated as they freely exercised their food preferences.

No rain fell in 1961 after March, and surface waters had disappeared by early May. Herbage, however, remained fairly plentiful until early winter, and the kangaroos did not lose weight till after August.

The variety, quantity and quality of palatable herbage continually declined throughout the last six months of 1961. The decline was least severe in the vicinity of mills, where (1) on heavier soils, trampling by sheep had suppressed spinifex and shrubs in favour of the introduced buffel and birdwood grasses; and (2) on lighter soils, the burning of old spinifex had stimulated the growth of a wide variety of forbs and soft grasses and of seedling *Triodia pungens*.

Throughout the year marloos maintained their preference for clayey plains sparsely vegetated with soft grasses, and euros for sandier country vegetated more densely with spinifex and shrubs. Nevertheless the contraction of the food supply resulted in increasing overlap between the diets of the two species of kangaroo, till in November there was no great difference between them. While the diet of the sheep showed a trend towards those of the kangaroos, there was still considerable disparity in November, when the sheep were eating much more browse than the kangaroos but very little spear grass (*Aristida* spp.).

In 1962, a much drier year, field estimates were made of the daily intake of dry matter by the two kangaroos. Adult male euros averaged 33.6 g/kg body-weight in February-March, and adult female marloos 28.4 g/kg in October-November (at a time when they and female euros were prevented by drought from rearing their pouch-young).

Peculiarities of time and place

Certain things limit the generality of the above results both for Mundabullangana and for the Pilbara as a whole. First, the dietary studies were carried out in an unusually good year. Several of the annual plants that were common in February 1961 were not seen by

Mr A. S. George (State Herbarium) when he accompanied us on Mundabullangana twelve months later. It seems likely, then, that in many wet seasons the diets would comprise fewer items than in 1961 and there would be less disparity between sheep and kangaroo diets, as well as less physical segregation between the animals.

Second, and more important, the present study area is typical of only a small portion of the Pilbara, viz. the best parts of the coastal plain and of the lower valley of the De Grey River (see map, Anon. 1962). Mundabullangana, in fact, lies at one end of a scale whose other extreme is well exemplified by Mt. Edgar, 25 miles southeast of Marble Bar and one of the study areas of Sadleir (1965) and of Ealey, Bentley and Main (1965).

The country at Mt. Edgar, though less hilly than its surroundings, has considerable relief, and its soils are largely skeletal. Hence much of the water from heavy rains is discharged via numerous gullies and creeks into the Talga River. In contrast, the deeper and loamier soils of Mundabullangana are greatly superior in their capacity for holding moisture, and because of the gentle topography drainage channels are poorly developed. Excess water gravitates to local hollows and low-lying plains; relatively little of it flows into the Yule and Little Yule Rivers. Consequently the seasonal distribution of rain is not so important here as at Mt. Edgar. As we have seen, there was sufficient soil moisture at Mundabullangana for the production in autumn and winter 1961 of abundant herbage on spinifex burns, even though no rain fell after March.

The climate, too, is more favourable on the coastal plains than in the interior. Daily maximum temperature at Roebourne averages 4-6°F lower than at Marble Bar in the period October-March, and throughout the year relative humidity is considerably higher at Roebourne. Conditions are thus more favourable for dew, which at Mundabullangana may alone suffice for continuous growth in scattered, heavily grazed tussocks of birdwood and buffel grass.

Conclusions

The following conclusions, I believe, will hold for most years and most parts of the Pilbara.

1. The quantity of nutrients available to sheep and kangaroos varies from year to year according to rainfall and management. Within a year the quantity generally declines from the end of one summer to the beginning or middle of the next. This decline may be locally arrested by either winter rain or the retention of soil moisture.

2. Of the two kangaroos, the marloo is dietetically the nearer to sheep. This is probably the main reason for marloos being resident and plentiful only in the better sheep country, viz. zone A of Anon. (1962). In the remainder of the Pilbara the marloo is a rare vagrant.

3. One of the principal differences between marloo and sheep diets is the much higher incidence in the latter of dicotyledonous forage. A similar disparity between marloo and cattle diets was observed by Chippendale (1962) in Central Australia.

4. Spear grasses of the genus *Aristida* constitute a major dry-season item in the diet of kangaroos, whereas sheep seldom eat these grasses when dry. Similarly in Queensland (Kirkpatrick, 1965), grey kangaroos (*Macropus giganteus*) commonly eat *Aristida* spp., all of which are relative unpalatable to sheep.

5. Of the three diets, the euro's includes the most spinifex and the least dicotlyedonous herbage. This is probably why the euro alone prospers in the rougher parts of the Pilbara, where spinifex overwhelmingly dominates the vegetation.

6. Though the three species are clearly differentiated in their food preferences, there is usually too little food for the free exercise of these preferences, and large dietary overlaps are inevitable. While kangaroos clearly eat food that would otherwise be available to sheep, neither the present research nor any other indicates the effect of this competition on the Pilbara wool industry.

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